Universitat de Lleida

Animal Science and Veterinary Medicine

Assessment of hoof angles in the Catalan Pyrenean Horse

FINAL DEGREE PROJECT

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2020-2021

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Treball de Fi de Grau

Paraules clau: Cavall Pirinenc Català, angles, conformació del casc equí.

Una bona conformació del casc equí indica un bon estat de benestar i salut dels animals. L'objectiu d'aquest treball de final de grau va ser estimar el valor mig pels angles dels cascos del Cavall Pirinenc Català, una raça autòctona catalana localitzada als Pirineus. Fotografies de la cara lateral de cada extremitat distal van ser obtingudes per a una població de 110 individus de Cavall Pirinenc Català. Les següents dades també van ser obtingudes per a cada cavall: sexe, edat, color del pelatge, eugassada, marques blanques de les extremitats (calçat), condició corporal i localització. Els angles de la pinça, taló, garreta i corona van ser mesurats. Es va elaborar una taula de continguts i es va efectuar una Non-Parametric Multivariant Anova (NPMANOVA) per estudiar les diferències entre angles i extremitats. Els resultats van mostrar valors superiors per l'angle de la pinça en comparació amb l'angle del taló. També van suggerir diferències entre cascos d'extremitats anteriors i posteriors, però no es van apreciar diferències entre cascos del costat dret i esquerre. Animals amb una condició corporal major i poltres van tendir a presentar valors més alts pels angles, mentre que animals amb alteracions al casc tendien a mostrar angles més aguts.

Palabras clave: Caballo Pirenaico Catalán, ángulos, conformación del casco equino

Una buena conformación del casco equino indica un buen estado de salud y bienestar del animal. El objetivo de este trabajo de fin de grado fue estimar el valor medio de los ángulos de los cascos del Caballo Pirenaico Catalán, una raza autóctona catalana localizada en los Pirineos. Fotografías de la cara lateral de la extremidad distal fueron tomadas en una población de 110 individuos de Caballo Pirenaico Catalán. Los

siguientes datos también fueron obtenidos para cada caballo: sexo, edad, color del pelaje, yeguada, marcas blancas de las extremidades (calzado), condición corporal i localización. Los ángulos de la pinza, talón, cuartilla y corona fueron medidos. Una tabla de contenidos fue elaborada y se efectuó una Non-Parametric Multivariant Anova (NPMANOVA) para estudiar diferencias entre ángulos y extremidades. Los resultados mostraron valores mayores para el ángulo de la pinza en comparación con el ángulo del talón. También sugirieron diferencias entre cascos de extremidades anteriores y posteriores, en cambio no se apreciaron diferencias entre cascos de extremidades del lado derecho e izquierdo. Animales con una mayor condición corporal y potros tendieron a presentar valores más altos de los ángulos, en cambio, animales con alteraciones en los cascos tendieron a mostrar ángulos más agudos.

Key words: Catalan Pyrenean Horse, angles, equine hoof conformation

A proper hoof conformation is a sign of health and welfare in horses. The aim of this final degree project was to estimate the mean values of hoof angles in the Catalan Pyrenean Horse, a local breed from the Pyrenees area in Catalonia. Pictures of the lateral view of each distal limb were taken in a population of 110 Catalan Pyrenean Horses. Not only pictures were taken, but also other parameters were recorded from each animal. These parameters included: sex, age, coat colour, herd, leg marking, body score condition and place. The angles of the toe, heel, pastern and coronet were included in this research. A table of contents was created and a Non-Parametric Multivariant Anova was performed in order to study the differences within all the limbs and between each angle. Results could show how the toe angle had significantly higher values than the heel angle. They also suggested significant differences between the conformation of forelimb and hindlimb hooves, meanwhile hooves from right and left pairs of limbs appeared to be similar. Animals with higher body score condition and foals had greater angle values, but hoof angles in animals that presented hoof abnormalities tended to be more acute.

INDEX

SUMMARY

A proper hoof conformation is a sign of health and welfare in horses. Shoeing and trimming are usually needed in performance horses to provide a good balance and force distribution among the hoof. The aim of this final degree project was to estimate the mean values of hoof angles in the Catalan Pyrenean Horse, a local breed from the Pyrenees area in Catalonia. These horses are mainly raised for meat under semi-extensive conditions using high mountain pastures in summer, so the values obtained for each hoof angle could be considered physiological. Pictures of the lateral view of each distal limb were taken in a population of 110 Catalan Pyrenean Horses. Not only pictures were taken, but also other parameters were recorded from each animal. These parameters included: sex, age, coat colour, herd, leg marking, body score condition and place.

The angles of the toe, heel, pastern and coronet were included in this research. A table of contents was created and a Non-Parametric Multivariant Anova was performed in order to study the differences within all the limbs and between each angle. Results could show how the toe angle had significantly higher values than the heel angle. They also suggested significant differences between the conformation of forelimb and hindlimb hooves, meanwhile hooves from right and left pairs of limbs appeared to be similar. Animals with higher body score condition and foals had greater angle values, but hoof angles in animals that presented hoof abnormalities tended to be more acute.

INTRODUCTION

The Equine Distal Limb

The hoof capsule has been described as a modified skin that covers the tip of the horse digit (Budras, Sack & Röck, 2011). This modified skin is composed by hard keratin, which gives to the hoof a great physical strength. It includes three layers of modified skin, but they are not uniformly distributed in all regions of the hoof. These layers are known as: epidermis, dermis and subcutis. The epidermis is the outer layer which is firm and regenerates continuously at the coronary band. This is the reason why it is used to be trimmed in performance horses (Pollit, 1998).

The dermis consists on a highly vascularised sensitive tissue underneath the epidermis which is commonly known as corion or quick. It is organised in papillae where arteries and veins are connected due to arteriovenous anastomoses (Butler et al., 1992).

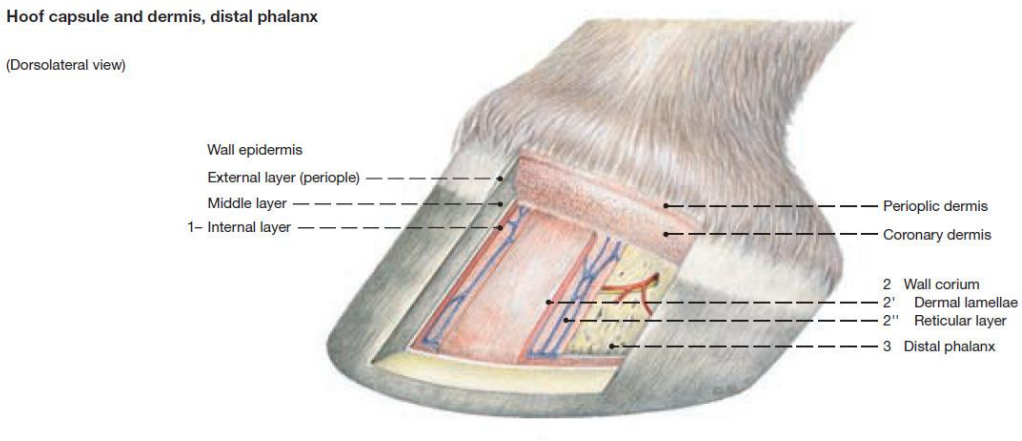

Fig. 1: Dorsolateral view of the hoof capsule and dermal layers
Budras K.D., (2011). *Anatomy of the horse* [Figure]

The hoof capsule is composed by the wall, frog, sole and bulb. The wall is the part visible on the standing horse. On the front of the hoof, the wall receives the name of toe. On the lateral and medial sides it is called quarters and finally, at the back of the hoof, there can be find the medial and lateral heels. The frog is a triangular shaped organ located in the palmar or plantar view of the hoof (Budras, Sack & Röck, 2011). It is known to have an important role in blood pumping (Butler et al., 1992).

The bulbs are located at the back part of the hoof above the heels and the frog (Budras, Sack & Röck, 2011).

The capsule covers relevant anatomical structures such as the distal phalanx, hoof cartilages, the distal interphalangeal joint and the distal sesamoid bone (also known as navicular bone). Other structures like tendons, ligaments, blood vessels and nerves can be found within the ones mentioned previously (Budras, Sack, & Röck, 2011)

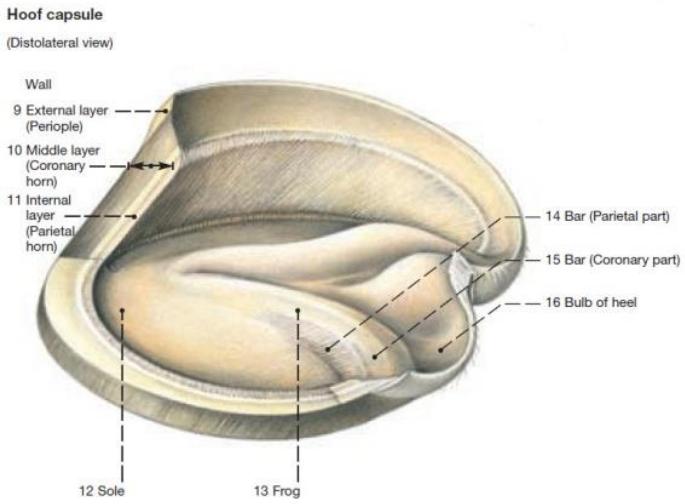

Fig. 2: Dorsolateral view of the hoof capsule. Budras K.D., (2011). *Anatomy of the horse* [Figure]

There are two kinds of forces acting on the hoof, the internal and the external ones. Internal forces are the ones exerted by the horse while the external forces are exerted by the ground. A hoof is balanced when forces acting upon it are in equilibrium, a state characterised by the cancellation of forces by acting equal opposed forces (Butler et al., 1992). Balance can be defined as a hoof preparation that enhances performance and interferes minimally with long term athletic ability (Balch et al., 1995). It can be assessed by comparing the hoof with imaginary lines of reference such as the toe or heel angle (Butler et al., 1992). Some studies have assessed hoof balance and health observing the position of the distal phalange by obtaining radiographs of the lateral view of the hoof (Kalka et al., 2020; Thieme et al., 2015).

The toe angle is described as the dorsal to solar angulation of the hoof measured at the toe. It is suggested to be between 50º and 54º, being similar in the forelimb and in the hindlimb hooves (Balch et al., 1995). The heel angle involves the palmar or plantar heel surface to solar surface and it has been considered to have the same values as

the toe angle. Historically it has been understood that the dorsal surface of the hoof toe is parallel to the pastern axis and the palmar or plantar surface is nearly parallel to the toe (Balch et al., 1995). However, recent studies proved that it is not physically possible for the dorsal and palmar or plantar surfaces to be parallel (Dyson et al., 2011; Powell, 2006). In spite of that, there is a lack of proper scientific information to support these concepts regarding to the angle values for a healthy hoof.

There is also a variable opinion whether the toe angle is greater or smaller in the forelimb in comparison with the hindlimb. It is suggested to be similar in both pairs of hooves (Balch et al., 1995; Cripps & Eustace, 1999; Powell, 2006), but other recent studies show different results between the forelimb and hindlimb hooves. A study performed in Thoroughbred racehorses describes the conformation of the hindlimb hoof and determines that the toe and heel angles of the hindlimb hoof are smaller than the toe and heel angles of the forelimb hoof (Kalka et al., 2020). Another study made using radiographic measurements in ponies also proves that forelimb hooves have greater toe and heel angles (Thieme et al., 2015).

The Catalan Pyrenean Horse

The Catalan Pyrenean Horse is a large breed of horse located around the Pyrenees area. It is mainly bred for meat under semi-extensive conditions using high mountain pastures in summer.

It was originated in the XX century by crossbreeding exemplars of the currently extinct Catalan Horse with European draft breeds. Some studies have suggested that Catalan Pyrenean Horses may be related with the Breton, Comtois and Ardanais horses (Jordana, Parés & Sanchez, 1995). It was known as “Pyrenean Hypermetric Group” due to the small amount of population, which reaches nearly 4.600 individuals, and their stocky conformation. In 2008 a studbook was published and their racial standard was accepted adopting the name of “Cavall Pirinenc Català” (Infante et al., 2009).

Following the guidelines of his studbook, the Catalan Pyrenean Horse is a heavy breed with a good sense of balance, showing a strong and harmonious appearance, and their coat is mostly chestnut, bay or black. Other less common coats can be seen, such as red roan or straw (Ordre AAR/184/2008, 2008).

The head should be big creating a straight cranial profile and nostrils are round shaped. The presence of canines is commonly seen in females. Their neck is short and strong, with a thick and coarse mane. They have a deep and compact body with well developed muscle mass as well as the rump. Withers should have a rounded appearance without being well defined (Ordre AAR/184/2008, 2008).

Fig.3: Catalan Pyrenean Horse

Their limbs are robust and strong but they are relatively short and thin in comparison with the rest of the body. Hooves are well developed to bear easily all the weight of the animal (Ordre AAR/184/2008, 2008).

They spend most of their live in natural pastures without receiving any hoof treatment, neither shoeing nor trimming. This is why some studies consider this breed to have naturally shaped hooves (Parés i Casanova & Oosterlinck, 2012).

The livestock production system used to obtain meat from this breed is semi-extensive. In springtime they are left on natural high-mountain pastures, where they spend time grazing until autumn comes. When winter arrives they are kept in large paddocks located in the valleys where they are fed with low-quality straw (Parés i Casanova & Oosterlinck, 2012).

The foaling season takes place in spring, which means that foals are born and in high-mountain pastures. Catalan Pyrenean Horse females are bred so that they can give birth easily without veterinary assistance and with low levels of mortality. When autumn comes and it is time to go down the valleys, foals are around six months old and weight between 220 and 250 kilograms. From that moment onwards either they can be sold in agricultural events or they can go to fattening farms. Facilities used in cattle are usually used in foals but in this case a space of $5m^2$ per animal must be respected. Foals stay

four or five there months and they are fed with concentrated and forage. Three different kinds of concentrated are usually used during the fattening period (Sagarra i Marín, 2007).

Hypothesis

The aim of this study was to assess the hoof angulation in the Catalan Pyrenean Horse as these horses live in natural conditions without effects of trimming or shoeing. This assessment also included age, sex, place, stud farm, coat, leg marking and body score condition as other parameters that could be related with hoof angulation.

The toe, heel, pastern and coronet angles were measured in pictures of the lateral view of the hoof. A previous study shows the accuracy of the angle measurement in photographs and proves that is a better method than hoof measurement devices (Moleman et al., 2005).

The main objectives of this final degree project were:

1- To estimate the mean hoof angulation of the Catalan Pyrenean Horse.

2- To determine if any horse traits or management variables can have an effect on hoof angle measurements.

3- To compare hoof angle values of each limb as some studies suggest that forelimb hooves have different values of hoof angulation than hindlimb hooves.

4- To discuss the reliability of the use of pictures as a way to obtain data from hoof angulation in horses under semi-extensive conditions

MATERIALS AND METHODS

Sampling

Data was collected from 110 grazing horses from La Cerdanya, a North East region from Catalonia close to the French border. Horses were randomly chosen from three different places where grazing conditions are not alike. A picture of the lateral view of the hoof was taken from each limb of all the horses included in the study. Not only pictures, but also other parameters were recorded from each animal. These parameters included: sex, age, coat colour, herd, leg marking, body score condition and place.

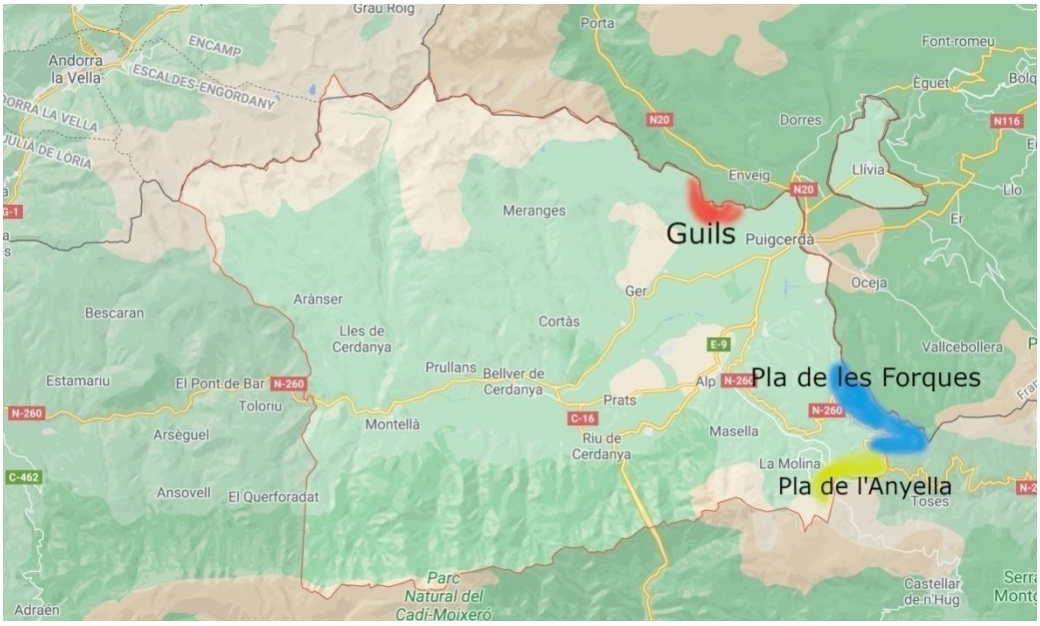

Fig.4: Map of La Cerdanya. Google (n.d.) [Google map of la Cerdanya] Retrieved December 18, 2020 from https://www.google.es/maps/

From these 110 horses 71 were adults (8 males and 63 females) and 39 were foals (17 males and 22 females). Regarding to the coat colour, most of them were chestnut (46), bay (25) and straw (19). Some pictures were taken to horses from other less commonly found coats: red roan (11), black (4), dapple grey (2) and piebald (3).

Leg markings were classified in: coronet, pastern, sock and stocking. The body condition score was established using a range from 1 to 5 (Carroll & Huntington, 1988).

Pictures were taken in three different places from La Cerdanya. Each one had different grazing herds. In the following shows the number of herds from each place and how many horses were photographed.

Table 1: Locations, stud farms and number photographed horses

Location	Herd							
	A	B	C	D	E	F	G	H
Pla de l'Anyella	11	9	16					
Guils				15	11	16		
Pla de les Forques							21	18

Ethical approval was not required as any procedure was carried out directly on the animals.

Acquisition of images

To measure the hoof angles, a picture of the lateral view of the hoof was taken from each limb using a digital camera (Nikon D5600). Pictures were taken when horses were standing still with both pairs of limbs in a parallel position creating a square. The neck was standing up in a normal position without grazing while pictures were taken. Horses where in the mountain, so it was difficult to find a completely flat zone, but big differences on the land inclination where avoided to make sure the horse position was as much natural as possible.

Image Analysis

Hoof angles were measured on the pictures using Digimizer© v. 5.4.7 software (available at https://www.digimizer.com/). From many different angles in the hoof, just the angles of the toe, heel, pastern and coronet were measured.

- **Toe angle**: it includes the dorsal surface of the hoof and the sole.
- **Heel angle**: it consists on the angle created by the palmar or plantar surface of the heel and the sole.
- **Pastern angle**: the pastern angle is created by the pastern axis and the sole.
- **Coronet angle**: the coronet angle is formed by the coronary border and the sole surface.

Fig.5: hoof angles studied: 1) Toe angle. 2) Heel angle. 3) Pastern angle. 4) Coronet angle.

To know the reliability of pictures as a way to obtain hoof angles measures in grazing horses, a second group was created with repeated pictures of 10 individuals.

Data analysis

A table of contents was created using Excel © in order to make easier the comprehension of the recorded data. Using PAST software © PAST v. 2.17c (Hammer et al., 2001) different multivariate analyses will be performed.

Preliminary analysis included a one-way Non Parametric Multivariant ANOVA to compare paired forelimbs and hindlimbs separately. Angular data were log transformed

for ulterior analysis before performing this test due to the use of qualitative variables. The main reason to perform a Non Parametric Multivariant ANOVA was the distribution of the data, as it was not considered to be a normal distribution. Another reason to use this test was the big amount of data obtained from the horses. The confidence level established was 95%. The aim of this test was to check the differences between right and left pairs of limbs, and forelimbs and hindlimbs. It was also used to compare the obtained results of these 110 horses with a second group formed of 10 horses, also included in the group of 110 animals, to check the reliability of the photography as a way to measure hoof angles.

Two-way Non Parametric Multivariant ANOVA was used to assess the influence of qualitative variables (coat, age group, gender, coat, body condition, hoof abnormalities and grassland area) on angle values.

A Principal Component Analysis was performed in order to determine which variables are the ones that make greater differences between individuals. A log transformation was not required in order to perform this test.

Finally, foals and animals with hoof abnormalities were excluded to create a mean standard values for hoof angulation in CPC. Mean ± standard deviation and minimum and maximum values were calculated for each angle. Means were differentiated in forelimb angles or hindlimb angles.

RESULTS

In total there were 440 pictures obtained. Signs of post-laminitis could be easily seen in some adults, so they were not included to obtain the mean values of hoof angulation. From all the 110 horses, just 23 healthy adult individuals were assessed as they had no abnormalities detected.

The Non-Parametric Multivariant ANOVA did not identify significant differences between the group formed of 110 horses and the second group, formed of 10 horses ($p=0.116$; $e=6.13\%$). It gives reliability to the use of photography as a method to obtain angle measurements in grazing horses. Significant differences were found when comparing forelimb hooves with hindlimb hooves. However, there were no significant differences between hooves from right and left pairs of limbs.

The toe angle in the forelimb was significantly more acute (50.9°±7.7) than the one in the hindlimb hoof (53.2°±6.3). On the other hand, heel angle was more acute in hindlimb hooves (45.1°± 7.4) than in forelimb hooves (48.2° ± 8.8). The pastern axis had the same inclination between the forelimb and hindlimb hooves (52.7-54.9°). Coronet angles were in a range between 20-30° in both pairs of limbs.

Focusing on the differences between hoof angles, the mean values of the toe and heel angle are significantly different. The toe angle is greater (50.9-53.3°) than the heel angle (45.0-48.2°) in both forelimb and hindlimb hooves.

Table 2: mean measurement results

	Forelimb				Hindlimb			
	Toe	**Heel**	**Pastern**	**Coronet**	**Toe**	**Heel**	**Pastern**	**Coronet**
Minimum	34.40	31.03	40.16	13.89	38.56	29.54	32.61	12.42
Maximum	65.66	67.06	79.20	36.48	69.18	63.05	67.65	36.58
Mean	50.95	48.16	54.98	22.59	53.25	45.07	52.71	24.39
Standard Deviation	7.68	8.75	7.84	5.50	6.27	7.36	9.31	6.27
coefficient of Variation	15.07	18.18	14.25	24.33	11.78	16.33	17.66	25.72

Some of the qualitative variables included in the study had some impact on the angle values. Individuals with higher body condition score had higher angle values than the others. Greater angle measures can be also seen in foals. Animals with hoof abnormalities appear to have lower angle values than the healthy ones. The location, herd, coat colour and leg markings do not look to have a significant impact on hoof angulation.

The Principal Component Analysis proved that the pastern angle is the most useful variable in order to differentiate forelimb and hindlimb hooves. The heel angle and toe angle also showed influence on the discrimination, but the most discriminative variable was the pastern angle.

DISCUSSION

This final degree project was designed to study the values of the different hoof angles in the Catalan Pyrenean Horse. Mean hoof angle values were estimated from a population of 23 healthy adults and hoof conformation was assessed for each pair of limbs in all horses.

Results could show significant differences between the value of the toe and the heel angle. Furthermore, the forelimb and the hindlimb hoof conformations did not appear to be alike. In this population the toe angle tended to be greater than the heel angle in both pairs of limbs. However, in the hindlimb hoof it appeared to be greater than in the forelimb hoof. On the other hand, the heel angle tended to be higher in the forelimb hoof in comparison with the hindlimb hoof. No differences were found between the right and left pairs of hooves.

These results reveal similarities to some studies performed in other breeds as they not only prove differences between the toe and heel angle, but also between the conformation of the forelimb and hindlimb hoof. In a recent study performed involving some different breeds of horses, the toe angle had greater values than the heel angle in both pairs of limbs. Although the toe angle was higher in both pairs of limbs, differences between forelimb and hindlimb could be found: the hindlimb hoof toe angle was larger than the one in the forelimb, while the heel angle was smaller in the hindlimb (Kalka et al., 2020). However, other studies cannot show differences between forelimb and hindlimb hoof angle measurements. Powell studied hoof angulation in 40 horses and created a three-dimensional model of hoof capsule made with plasticine. Straight lines were drawn from the sole to the coronet along the hoof wall, but they failed to be parallel and they did not have the same angle with the floor. Horses included in this study had similar toe angle values in both pairs of limbs, unlike in this final degree project, but the toe angle appeared to be greater than the heel angle (Powell, 2006).

It is important to bear in mind that horses involved in this study did not receive any sort of shoeing or trimming treatment unlike in other studies. This fact gives consistency to the argument of physiologically having different values for the toe and heel angle. Kalka studied the hoof conformation in different breeds of horses and obtained greater values for the toe and heel angle in unshod horses even when adjusted for breed differences (Kalka et al., 2020). A study made in Australian feral horses proved the

significant effect of the hardness and travelled distance. Horses that travelled longer distances in a harsh ground had larger toe and heel angles (Hampson, 2011). It suggests that not only shoeing and trimming treatments can have influence on the angle values, but also it is important to note that Catalan Pyrenean Horses are raised in semi-extensive conditions unlike horses from other studies.

The anatomy of the equine distal limb also shows differences between the distal forelimb and hindlimb and this fact can explain their dissimilarities regarding to the values of hoof angles. The forelimb hooves bear approximately the 60% of the body weight and are more rounded through the toe and quarters. Hindlimb hooves tend to be more upright, which means that pastern angle is more obtuse (Budras, Sack & Rock, 2011). In a proper hoof conformation the dorsal surface of the wall is parallel to the axis of the pastern. This anatomical feature can explain the reason why toe angles in the hindlimb tend to be more obtuse. Despite this, the results coming from other similar studies are very variable as some of them do not show differences between forelimb and hindlimb hooves (Balch et al., 1995; Cripps & Eustace, 1999; Powell, 2006). It is also important to consider the limited evidence-based literature that describes the conformation of the hindlimb hoof.

Another substantial difference between forelimb and hindlimb hooves is the biomechanical function of each pair of limbs. A study performed in order to determine the kinematic differences between the distal forelimb and distal hindlimb reported that the distal forelimb is under greater kinematic stress than the distal hindlimb at the beginning of the stance phase (when the hoof is in contact with the ground). It also showed that vertical hoof velocity at impact and the resulting vertical hoof acceleration were higher in the forelimb than in the hindlimb. On the other hand, horizontal hoof velocity at impact and the resulting horizontal acceleration were greater in the hindlimb (Back et al., 1995). It was reported in a review that the duration of the stance phase of the trot is longer in the hindlimbs (Leach & Dagg, 1983).

Such functional differences can help to understand the reason of the slight anatomical variation between distal hindlimb and distal forelimb, as the hindlimb hoof and pastern tend to be more upright. These anatomical and functional differences between these pairs of limbs can affect hoof conformation due to a variation on hoof growth. These facts suggest that hoof growth may be more affected in the forelimbs as the stance phase is longer and a 60% of the horse body weight lies on them.

The PCA test could show that the variable that tends to be more useful in order to distinguish between distal forelimb and distal hindlimb was the pastern angle. The heel

angle also had a great influence in hoof conformation, but regarding to the results the pastern angle appeared to be the best variable in order to distinguish pairs of limbs. Despite of these results, it does not mean other variables cannot discriminate groups. It is expected to be that way due to the anatomical differences between forelimbs and hindlimbs exposed previously.

There were no significant differences between right and left pair of limbs. A previous study performed in Catalan Pyrenean Horses did not show any differences between right and left limbs for any hoof conformation parameters, which enhances the idea that hooves are similar in both sides of the horse (Parés i Casanova & Oosterlinck, 2012). However, other studies could not prove the same similarities. Thieme described hoof conformation in a group of ponies and her results showed differences between right and left pairs in some parameters such as the hoof length and balance. Left hooves appeared to be longer either in the forelimbs or in the hindlimbs (Thieme et al., 2015). It was also reported in a study performed in riding school horses that the left hoof tends to have lower toe angle (Leśniak et al., 2019).

Motor laterality has been observed in grazing horses as they tend to protract a front leg, but it has also been seen in sport horses when they do not show the same level of balance in both sides. This fact is also known as motor bias, but not all the horses have the same degree of it. Young foals have been reported to develop laterality while grazing (Van Heel et al., 2006). A study performed by the University of Georgia determined the relationship between motor laterality and hoof growth, but it did not show any difference between the growth pattern of horses with motor bias and the one of horses without motor bias (Towe et al., 2019). Van der Heel studied a group of 3 year-old foals and concluded that animals with significant laterality for one side had four times more hoof unevenness (Van Heel et al., 2010). Hoof shape, wall and size can be different between breeds, but the hoof has to be proportional to the size of the horse (Łuszczyński et al., 2015). Body weight has been reported to have a significant influence on hoof conformation as larger horses tend to have a more upright hoof shape (Leśniak et al., 2019).

These facts can help to understand the different results between studies. Ponies may have slightly different shaped hooves than the Catalan Pyrenean Horse because it is not the same breed and the Catalan Pyrenean Horse is significantly bigger and heavier. Ponies and horses used in the studies cited previously were not in grazing conditions, as they were used for sport. Laterality may have influence either in ponies, riding school horses or Catalan Pyrenean Horse, but the use of these animals is

different. Catalan Pyrenean Horses live under semi-extensive conditions while others are involved in activities that require facing stronger reaction forces from the ground. Another considerable difference between the horses of this study and the horses included in the previous ones is the lack of trimming in the Catalan Pyrenean Horse. The use of the horse and housing conditions can have an important role in hoof conformation as they cause different stain in forelimb and hindlimb (Łuszczyński et al., 2015)

The angle of the toe and the angle of the pastern did not show significant differences. Forelimbs, when viewed from the lateral side, should ideally form a straight line from the elbow joint to the fetlock, with a normal angle of pastern and foot angle about 54° (De Souza et al., 2004). If the pastern axis is not aligned with the dorsal hoof wall hooves can be described as “broken forward” or clubbed foot”; the toe angle is raised. In this case the pastern would be pushed forward and cause a concave break in the line. A convex break in the line occurs when toes are too elongated; in this case the toe angle is lowered. Raising the hoof angle increases the tension in the superficial digital flexor tendon and decreases it in the deep digital flexor tendon. If the angle is lowered the superficial digital flexor tendon has less tension while the tension increases in the deep digital flexor tendon (Balch et al., 1995). The mean pastern angle for the hooves in this population was 54.98° and horses did not show any clinical lameness although some individuals appeared to have broken forward hooves. It means that this population of Catalan Pyrenean Horses do not look to have any hoof conformation faults.

Coronet angles presented a range between 20°-30°. Other studies show similar values within this range for the coronet angle (Dyson et al., 2011; Kalka et al., 2020; Kolstrung et al., 2013; Thieme et al., 2015). The results present a high coefficient of variation for this angle (25.72%), which indicates a high variability within individuals. Kolstrung, studied the mean hoof angulation within different breeds and his results not only show an important differentiation between individuals, but also there was a breed effect on angle measures (Kolstrung et al., 2013). The Catalan Pyrenean Horse is a breed that has influence of Breton, Comtois and Ardanais horses (Jordana, Parés & Sanchez, 1995). Infante analysed the genetic variability within this breed and concluded that the Catalan Pyrenean Horse has high levels of genetic variability and low levels of consanguinity (Infante et al., 2009). This fact can justify an elevated coefficient of variability for the coronet angle as the breed has influence on angle values and the Catalan Pyrenean Horse is a breed with an elevated genetic variability.

Animals with higher body score condition and foals appeared to have larger values for hoof angles. The hoof of a new born foal has a gelatinous membrane in order to reduce the trauma in the uterus of the mare or during parturition. When foals take their first steps this membrane dehydrates and retracts proximally creating a groove just distal to the coronet. During this stage the coronet of the foal is generally wider that usual and the hoof wall gets narrower distally, at the ground surface (O'Grady, 2020). It means that hoof conformation in foals must be slightly different than in adult horses. Foals included in this study had higher hoof angle measures than adults. Another study performed in foals showed that the younger the foal, the higher the measures of hoof angles (Bhatnagar et al., 2009). Furthermore, it also indicated that foals can be "broken forward" but pastern angle decreases up to 7° for the firsts two months (Bhatnagar et al., 2009). However, there is a relative lack of scientific studies about foal hoof conformation and trimming.

Leśniak performed a study of how body weight and height at the withers can affect hoof conformation. Results could determine how both variables affected hoof conformation, but the influence of body weight was significantly greater (Leśniak et al., 2019). Łuszczyński determined that hooves must be proportioned to the size of the horse (Łuszczyński et al., 2015). These facts help to understand the positive effect of body condition score on hoof angle values for this population of Catalan Pyrenean Horses. A study performed in working horses from Fiji could relate the decrease of body condition score with foot neglect as hoof pain can cause inappetence (Fröhlich et al., 2020). This would not be the case of the studied population of Catalan Pyrenean Horses as any lameness could be observed.

Hoof abnormalities tended to cause a negative effect on hoof angle values for the studied population of Catalan Pyrenean Horse. Hoof abnormalities found in this population were mainly horizontal grooves or wall fracture, but as it has been said along this final degree project, horses could undertake locomotion functions properly. They may be related with harsh condition environment or sudden nutritional changes, as they were in grazing conditions. Hoof quality is influenced by blood and nutrients supply (Van Amstel & Shearer, 2001). If there is a poor blood supply or a deficiency of nutrients, it will have a negative impact on hoof growth. Not only depends on internal causes of the animal, but also external conditions can have a negative effect on hoof development. For example, under extremely dry conditions the hoof wall can become very hard; or very soft and flexible if the environment has elevated moisture (Redden, 2003).

This population of horses had a similar amount of abnormalities in the forelimbs and in the hindlimbs. Usually, horses tend to have more abnormalities or faults in the forelimbs because there is where the 60% of the body weight lays (Budras, Sack & Röck, 2011). Studies performed in order to understand biomechanical differences between forelimb and hindlimb hooves can prove how forelimb hooves are more likely to present abnormalities (Back et al.,1995; Leach & Dagg, 1983). Łuszczyński studied the frequency of faults in hoof conformation in different breeds and concluded that forelimbs are where most of hoof abnormalities can be found. It also reported an influence of the breed regarding to the type of hoof conformation fault or disorder. Not only the breed determines the health of the hoof, but it can also be affected by the use of the horse or the the way of management (Łuszczyński et al., 2015). Regarding to Łuszczyński, the ground surface, exercise, shoeing or trimming can predispose a horse to suffer from hoof conformation faults (Łuszczyński et al., 2015).

The mean values of hoof angulation obtained in this population of Catalan Pyrenean Horses could be considered physiological due to the semi-extensive conditions in which the animals are kept and the lack of shoeing or trimming. Hoof angulation values of horses with abnormalities and foals were excluded in order to obtain mean standard values. However, as it has been exposed previously, there is a “breed effect” in hoof angulation values. Not only the breed can affect these values, but also horse management plays an important role in hoof growth.

These results could be applied to assess hoof conformation in Catalan Pyrenean Horses, but it would not be right to apply these values to evaluate animals from other breeds or other sort of management. Hoof conformation must be assessed bearing in mind the breed of the horse, the activity they perform and their environment. The animal may require a trimming or shoeing treatment depending on these facts, but as it has been said, it would be wrong to try to obtain the measures of the hooves of Catalan Pyrenean Horses for a sport horse, for example. It is also important to consider that the mean standard values obtained belong to a population of 23 healthy adults, which means there would be limitations in order to extrapolate these values to the rest of the individuals of Catalan Pyrenean Horse.

The method used to obtain data proved to be suitable for assessing hoof conformation in horses reared under extensive conditions. It could also be used in feral horses or other kind of ungulates that live in similar conditions. However, there are limitations using this method. For example, grass, shadows or fluffy pasterns can add difficulties to the assessment of the hooves. The ground surface can also be a limitation as

horses should be in a flat ground avoiding inclinations, as the angles of the pastern and the coronet can be slightly modified.

Hoof conformation in the Catalan Pyrenean Horse has been assessed in this study. However, other studies should be performed in order to assess completely the hoof conformation of this breed as this final degree project is only focused on the lateral view of the distal limb. There are other variables that define hoof conformation, such as the length of the hoof wall or the assessment of the dorsal and solar views. Studies involving these features, that by the moment remain unknown for this breed, would be useful in order to increase the accuracy of hoof assessment for the Catalan Pyrenean Horse. It could also be interesting to observe the position of the third phalanx by performing a radiological study of the hooves. However, the use of radiology in this breed would suppose many difficulties due to the management of the horses.

CONCLUSION

The mean standard values for hoof angulation in the Catalan Pyrenean Horse were obtained. However these values must not be used in to evaluate hoof conformation in other breeds as they can be influenced by the management of the horse and the breed. Results have proved how it would not be possible to apply standard values of 45° for all the angles in all the hooves as they could show differences between the toe angle and the heel angle.

The qualitative variables studied did not appear to have influence on hoof angulation, except the age, body condition score and hoof abnormalities. Foals and animals with a greater body condition score tended to have higher values of hoof angulation. However, hoof abnormalities had a negative effect on hoof angle values.

Differences between forelimb and hindlimb hooves were also found. The toe angle tended to be more acute in the forelimb hooves than in the hindlimb hooves. However, the heel angle appeared to be greater in the forelimb hooves. Anatomical differences between the equine distal forelimb and the equine distal hindlimb can explain the obtained results as hindlimb hooves tend to be more upright.

The use of pictures as a way to collect data proved to be a reliable method to assess hoof conformation. It also showed to be useful in studies in which feral horses are involved as it does not require animal handling.

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